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Nouns and verbs are retrieved with differently distributed neural systems

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ABSTRACT **In a task designed to elicit the production of verbs, the patients known as AN-1033 and Boswell consistently produced the correct target words, performing no differently from normal controls. However, in a similar task designed to elicit the production of nouns, both patients performed quite defectively, and their scores were many SDs below those of controls. Language processing was otherwise normal—i.e., there were no impairments in grammar, morphology, phonetic implementation, or prosody; reading and writing were normal. In a third patient (KJ-1360), we obtained the reverse outcome—i.e., retrieval of common and proper nouns was preserved, but verb retrieval was defective. Together, the findings in the three patients constitute a double dissociation between noun and verb retrieval. In AN-1033 and Boswell, the lesions are located outside the so-called language areas (left frontoparietal operculum, posterior temporal region, inferior parietal lobule), where damage is associated with aphasia. The region of damage shared by the two patients is in left anterior and middle temporal lobe. This sector of left hemisphere contains systems for the retrieval of nouns that denote concrete entities. We propose that those systems are not essential for the retrieval of verbs and are not involved in the vocal implementation of word forms. Those systems perform a two-way lexical-mediation role for concrete nouns and promote the reconstruction of a word form after the processing of sensory–motor characteristics of the entity denoted by that word. The findings in patient KJ-1360, whose lesion is in left premotor cortex, suggest that equivalent mediation systems for verbs are located in the left frontal region.**

In previous studies with patient Boswell, we have found that he consistently fails to retrieve the concept behind the picture of certain classes of entity (the prime example being many natural kinds such as animals), whereas he invariably retrieves the concept for the actions performed by any entity, including those entities he no longer knows, and also retrieves the concept for the relationships assumed by any entity, abstract and not (1). The inevitable implication of this finding is that the neural systems that support retrieval of concepts of actions and relations are not the same as those that support retrieval of concepts of concrete entities. This finding complements previous discoveries regarding the discrete neural systems that seem to be devoted to the access of concepts of different categories, such as faces, natural nonface entities, and man-made entities (1, 2). In the study reported below, we wanted to establish whether this dissociation in conceptual access had a counterpart in a dissociation of access to concrete nouns and verbs, the word forms that denote concrete entities and actions, respectively.

MATERIALS AND METHODS

The target subjects for these experiments were patients AN-1033 and Boswell, whose neurological and neuropsychological characterizations have been published (3, 4) [and whose lesions lie outside the so-called aphasia-associated (5) areas] and patient KJ-1360, who had a left premotor lesion. The lesions of the three subjects are depicted in Fig. 1. Neither AN-1033 nor Boswell is aphasic in the traditional sense, and the two provide an ideal contrast because AN-1033 can access all classes of concepts with which he has been investigated but has a selective defect in lexical retrieval, whereas Boswell, as noted above, has a selective defect in both concept retrieval and lexical retrieval. KJ-1360 completes the contrast. He, too, has normal concept retrieval and a selective lexical-retrieval defect, in the absence of any other linguistic impairments (this patient had transient changes in language processing of the transcortical motor type but has fully recovered). The performances of the brain-damaged patients were compared with those of 10 controls, who were neurologically healthy individuals chosen to match the intellectual capacity and demographic characteristics of the target subjects.

In the noun-retrieval task, there were two types of stimuli. The one designed to probe common nouns consisted of slides depicting nonunique concrete entities, drawn from various conceptual categories. The stimuli included the 260 Snodgrass and Vanderwart (7) line drawings, supplemented by 40 line drawings and 100 photographs, all presented in canonical views in black-and-white. Here we report results on three key categories: animals, fruits/vegetables, and tools/utensils. The subject was asked to produce the precise target word at basic object level, which is the most specific and has the highest communication value for a nonunique entity—e.g., the pictures of an apple and raccoon must be named as "apple" and "raccoon" and not be named as "fruit" and "animal." When the response was not at basic object level—e.g., if the subject named a superordinate category but did not name the entity itself ("That's some kind of animal."), the examiner encouraged a more specific response ("What kind of animal?"). No time limit was imposed, and the next stimulus was presented whenever subjects indicated that their response was finished.

The stimulus set designed to probe proper nouns consisted of slides depicting faces of persons well-known to the subject. The set included "personal" faces (e.g., the subject's family members, friends) and "public" faces (e.g., politicians, actors). The faces were shown in frontal views in black-and-white slides, in random order, and the subject was requested to name each specific person ("Who is this?").

If subjects failed to respond or gave "don't know" responses in the noun-retrieval tasks, the examiner requested the category-level name—e.g., "What is it, in general; to what category does it belong?". None of the subjects had a defect in this regard—i.e., when asked the category, they all called faces as faces, animals as animals, tools as tools, and so on, even when specific naming at basic-object level was missing.

In the verb-retrieval task, the stimuli were black-and-white line drawings and photographs from the Iowa Verb Elicitation Test ($n = 153$) and from the Action Naming Test ($n = 57$)

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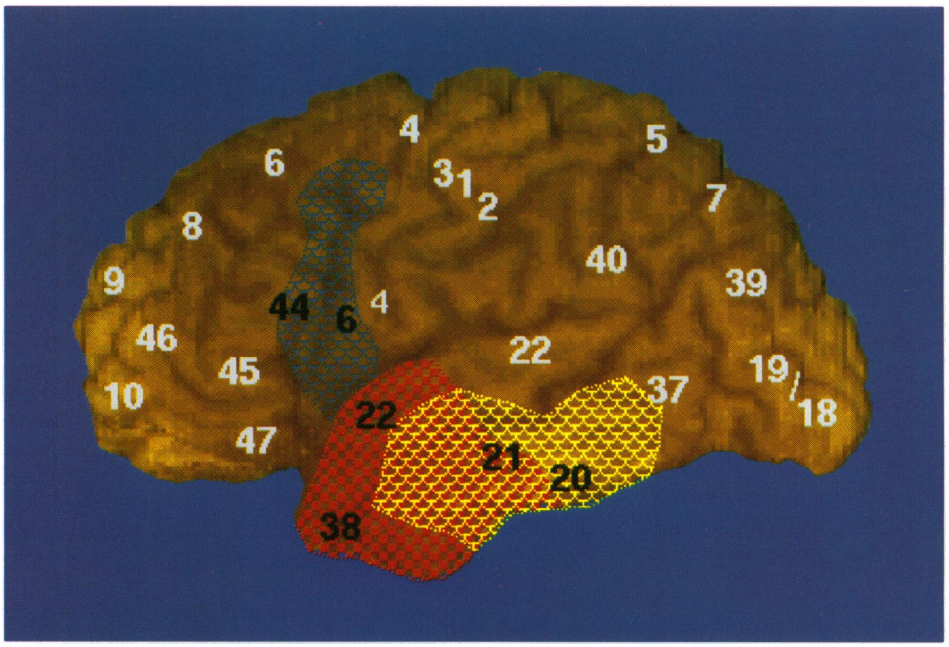

FIG. 1. The image shows superimposed plotting of the lateral extent of the left-hemisphere lesions in the three subjects (red, Boswell; yellow, AN-1033; and blue, KJ-1360). The lesions were plotted on a normal human brain reconstructed in three dimensions by BRAINVOX (6). Numbers represent cytoarchitectonic areas according to Brodmann nomenclature. (*i*) Boswell has bilateral lesions that include the mesial temporal region (amygdala, entorhinal cortex, hippocampus), the lateral temporal cortices (polar region, anterior segment of the first, second, and third and all of the fourth and fifth temporal gyri), the basal forebrain and anterior cingulate, and the internal capsule. The left premotor and prefrontal cortices are intact. (*ii*) AN-1033 has a left anterior temporal lesion that contains mesial and lateral regions. The lateral lesion involves most of the second and third temporal gyri and the anterior segment of the fourth temporal gyrus. The left premotor and prefrontal cortices are intact. (*iii*) KJ-1360 has a left premotor lesion in the posterior segment of the inferior frontal gyrus and the anterior segment of the precentral gyrus. The temporal lobe is intact.

(8). The subject was requested to indicate "What is happening?," as precisely as possible.

All naming tasks were presented on two occasions to the three brain-damaged subjects. On the first, the subject was requested to produce naming responses orally; on the second, the response was written. Only the oral-response format was used with the control subjects.

RESULTS

Analyses of word frequency [taken from Francis and Kucera (9)] and word length (number of letters in the word) were conducted to determine their role in the results (the proper nouns were not subjected to these analyses). For each variable, a one-way ANOVA with category as the independent variable (animal, fruits/vegetables, tools, verbs) was conducted. Regarding word frequency, the overall effect in the ANOVA was nonsignificant ($P > 0.05$), and a Duncan multiple-range follow-up test indicated that names of "tools" had greater frequency than names of "fruits/vegetables"; there were no other intercategory differences. For word length, the overall ANOVA was significant ($P < 0.001$). A Duncan follow-up indicated that the animal word length (6.0 letters) was significantly shorter than the other categories (7.1, 7.5, and 7.6 letters, for fruits/vegetables, verbs, and tools, respectively), none of which differed significantly from each other. These outcomes indicate that the verb and noun sets did not differ in any simple or consistent manner in word frequency and word length; hence, the following results cannot be explained on the basis of these factors.

For each set (three of common nouns; one of proper nouns; one of verbs) and for each response format (oral, written), a percent correct score was calculated by dividing the number of correct naming responses by the number of stimuli in the set. A correct naming response was defined as that which matched the common nouns or verbs produced by normal controls or that was the correct proper noun for the stimulus. The scores of the target subjects were interpreted in the context of the range and SD of control subject performances. The oral responses were used for this comparison. In fact, there were no differences between the brain-damaged subjects' performances as a function of response format (i.e., the performances were essentially equal in the oral compared with the written formats), and the detailed results presented below are from the oral-response task.

The results are presented in Table 1. Examples of incorrect naming responses are shown in Table 2. Boswell and AN-1033 had severe impairments in proper names, and both also had marked defects in retrieval of common nouns. In both, common nouns were far more impaired in the animals and fruits/vegetables categories than in the category of tools/utensils. Even in the less-affected noun category, however, both performances were >4 SDs below those of the control subjects. In a striking contrast, Boswell and AN-1033 were virtually perfect in the verb-retrieval task; their performances were equal to those of the controls. In KJ-1360, the opposite

Table 1. Noun and verb retrieval

	Proper nouns, %	Common nouns, %			Verbs, %
		A	F/V	T/U	
Boswell	*4*	*24*	*25*	*76*	92
AN-1033	*8*	*51*	*54*	*70*	96
KJ-1360	78	91	88	95	*53*
Controls					
Mean score ± SD	89 ± 6.2	92 ± 4.3	92 ± 5.4	94 ± 3.8	95 ± 2.8
n	(61)	(97)	(58)	(58)	(210)

Scores are percent correct; values in italics indicate defective retrieval. A, animals; F/V, fruits/vegetables; T/U, tools/utensils.

Table 2. Examples of errors

Patient	Stimulus	Response
Boswell	Duck	Bird . . .
	Penguin	Bird
	Pineapple	Possibly vegetable
	Zebra	Horse
AN-1033	Ostrich	Bird that sticks head in sand
	Raccoon	Animal . . . washes its food
	Zebra	Horse-like animal with black and white stripes
	Pumpkin	Melon . . . use it on Halloween
KJ-1360	Cutting	Going . . . scissoring
	Sailing	Sailboating
	Conducting	Band director
	Digging	Getting ready to move dirt

pattern of defect emerged. He was within 2 SDs of the normal mean in retrieval of names of animals, fruits/vegetables, tools/utensils, and familiar faces, but his retrieval score for verbs was severely defective, in spite of the fact that he could retrieve the concepts for the actions he could not name.

We have repeated the entire set of naming experiments in the brain-damaged subjects, and the response profiles were stable and reliable—i.e., the same levels and patterns of performance emerged across different experimental epochs. In some cases, there were minimal improvements in performance on the order of 4–6%, but this is well within the range that would be expected, given some practice effects and familiarity with the tasks. It is interesting to note that, although the levels and overall patterns of performance remained stable, items were not passed or failed with complete reliability from one epoch to the next. About 5% of the items were failed at one epoch but passed at the next or *vice versa*. This outcome is consistent with the notion that the subjects have a retrieval failure rather than a loss of lexical information. If the latter were true, it would be expected that failures would be invariant across task repetitions; a retrieval failure account, by contrast, predicts a certain degree of variability from one occasion to the next. (The dissociation between defective noun retrieval and normal verb retrieval has now been replicated in four subjects whose lesions are similar to that of subject AN-1033; the reverse dissociation between defective verb retrieval and normal noun retrieval has been replicated in three subjects whose lesions are similar to that of subject KJ-1360.)

DISCUSSION

The classic double dissociation we uncovered suggests that there are relatively separate lexical-mediation systems for concrete nouns and verbs. The systems that appear essential for retrieving proper nouns and certain classes of common nouns are in left anterior and middle temporal cortices. (Other common nouns can be retrieved from systems in left posterior temporal and occipitoparietal cortices; we and others (10) have found that damage to those systems does not compromise verb retrieval.) We had hypothesized that the systems essential for verb retrieval were in left frontal cortices. The rationale for this hypothesis came from the observation that damage to left frontal cortices impairs the retrieval of verbs more markedly than the retrieval of nouns (5), an observation supported by studies in which verb retrieval was more defective than noun retrieval in aphasics with presumed left frontoparietal damage (11–14). The finding of normal verb retrieval in patients Boswell and AN-1033, whose left frontal cortices are intact, and the finding of impaired verb retrieval in patient KJ-1360, whose left frontal cortex is damaged, support the hypothesis.

As far as lesion studies are concerned, the finding that noun retrieval is compromised by lesions in left anterior temporal cortex, outside the areas where damage traditionally causes aphasia, is unusual. However, this finding is in accordance with the results from studies in which the exposed human cerebral cortex was electrically stimulated during surgery for epilepsy (15).

Our results reveal defective noun or verb implementation under particular experimental constraints (in which a visual, nonverbal stimulus requires an oral or written response). But they do not signify a loss of the representation of the particular word for which oral or written implementation failed. For example, the words unretrieved in our experiments can still be retrieved under other conditions (e.g., phonemic cuing, running speech); also, in some cases, the words that were missing at one experimental epoch were retrieved correctly at another session. These findings indicate that word forms can still be reactivated from their highly distributed and fragmentary base representations in auditory, kinesthetic, and motor cortices. The failure seems to be in a mediation stage between the processing of a concept and the vocalization of word forms. Elsewhere we have proposed that there is a considerable anatomical separation for systems that support concepts, language, and the two-way-access mediation between the two (16).

Our interpretation differs from the traditional view on the neural basis of language in many respects. (*i*) We do not think that either concepts or word forms are represented in a permanent and integrated manner and in one neural site. On the contrary, they depend on many interacting networks that hold the potential for reactivation of components of concepts or components of word forms within recursive networks (17–19). (*ii*) We do not believe that the connection between conceptual structure and word-form implementation is a direct one. We believe, instead, that it depends on a mediational set of neural structures that use convergence zones and their feedforward–feedback connections, to link separate regions. The dissociations described above, by revealing intact conceptual and word-form processing but impaired interaction between the two, provide further evidence that such mediational systems exist in the human brain.

The most intriguing implication of our findings has to do with large-scale organization of brain systems for concepts and language. Our findings concern mediation systems for knowledge access. They suggest that the systems that mediate access to concrete nouns are anatomically close to systems that support concepts for concrete entities. Our findings also suggest that systems that mediate access to verbs are located elsewhere and are anatomically close to those that support concepts of movement and relationship in space–time.

The concepts denoted by concrete nouns typically have a hierarchical structure, one in which many levels are required to specify the multiple sensory–motor interactions that a concrete entity engages with the perceiver (20). We have reason to believe that the neural substrate for the representation of these many levels-of-entity knowledge rests on several cortical-processing streams that are aimed at the anterior temporal regions (1, 20). Those parallel and interlocking streams are constituted by varied cortical regions, connected by recursively organized corticocortical projections, and it appears that there is a principled connection between the position of the region in the stream and the level of knowledge complexity that can be accessed from the region (20). For instance, knowledge about entity features (e.g., color) depends on regions early in the streams—i.e., close to primary visual cortices, whereas knowledge about whole entities or about unique entities, respectively, depends

on regions progressively higher up in the streams—i.e., closer to their apex in anterior temporal region—namely, the entorhinal cortex. It is, thus, intriguing to discover that the retrieval of the nouns that denote whole concrete entities depends on structures at the very end of the processing streams, located in the left anterior temporal region. It is as if, after representing all levels of knowledge of a concrete-entity concept, the brain finally represents its name.

The structure of concepts denoted by verbs, on the contrary, is less stratified, in keeping with the requirement to represent manners of action of an entity and trajectories of an entity in space–time, rather than the multiple and embedded sensory–motor attributes that define an entity (21). Networks in the dorsal component of temporo/occipital and parietal cortices, which project to the premotor and prefrontal regions, are the likely substrate for this system because they can process visual and somatosensory aspects of the motion of an entity, intrinsically and in space–time (20). Again, it is intriguing to find that verb retrieval depends on left frontal structures that are the very end of the processing streams of that type located in the left hemisphere. It seems plausible that the systems that enact the two-way linkage between concrete entity concepts and the corresponding nouns, or action concepts and the corresponding verbs, should also be relatively separate, although interactive.

In addition to showing that noun and verb retrieval are operated from different systems, the results also suggest a relative system segregation for different categories of nouns. This is the preliminary conclusion to be drawn from the difference in the impairments for proper nouns and different categories of common nouns. Other investigators have found this dissociation in patients whose lesions were presumably similar (22).

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